ings seems hopeless in any conditions, save possibly in a thunderstorm, when we remember that all the bells and wires are in good electric contact with each other, and in more or less indifferent contact at many places with pipes, walls, &c. Further, only the bell at the end of a row could be rung by electrical attraction to the opposite wall, because the bells swing parallel to the wall on which they are fixed, and considerable force is required to make them move in a direction at right angles to their free swing.

In the case referred to by Mr. C. L. Tweedale, it might have been worth while to see if the wire attached to the lively bell he mentions did not come in contact with any other wires at any part of its length. What makes me suggest this is that in one of my rooms I can tell when the front-door bell is rung by a sympathetic movement of the bell-pull in the room, due to the wires rubbing against each other at some part and the wire to the door bell pulling the wire to the room.

When one considers the class of workmanship put into bell-hanging, one need not be surprised at the vagaries of the bells. Like plumber work, it is mostly out of sight, and as the work has often to be done in very imperfect light and under cramped conditions, anything that will work is considered good enough. JOHN AITKEN.

Ardenlea, Falkirk, August 21.

FLYING ANIMALS AND FLYING MACHINES.

UNTIL quite recently human flight was considered by the mass of mankind as so impracticable that "I can no more do that than fly" was a phrase used to denote something not to be accomplished. It is no wonder, then, that the fact that several people (probably some dozens at the present moment) have actually flown should appeal to the popular imagination, and the appeal is especially strong in such a case as M. Blériot's flight over the English Channel, although there is nothing really more formidable in a flight over water than over land. It may be of some interest to show briefly how it is that what was formerly looked on as a typical impossibility has now become a matter of everyday occurrence.

It will be a help to take first the case of such animals as have wings, and to see why it is that no creature the height of which approaches even one-quarter that of a man has been able to fly either in present or former times. In order that the wings may support the body, their movement must generate a downward current of air of which the momentum per unit of time is equivalent to the downward momentum which the body and wings would acquire in the same time under the influence of gravity. This does not necessarily involve a large expenditure of work. For instance, when a weight is attached to a parachute and is dropped from a height the speed of descent soon becomes constant, and the work done in the air by the parachute is then just equal to the product of the weight into the distance fallen. The resistance of the parachute is proportional to its area, and the speed of descent can be made as small as we please if the area is made large enough. The work, therefore, expended in a given time, that is, the power delivered to the air, is diminished in the same proportion.

Suppose now that instead of an inanimate weight an animal is suspended from the parachute by a long rope ladder. When the speed of descent is slow enough, the animal will have no difficulty in climbing the ladder at such a rate that the centre of gravity of the "system" may remain stationary in the air, and this by an expenditure of work which can be diminished indefinitely by increasing the area of the parachute.

This case is analogous to the hovering of a bird in the air without horizontal velocity during the downstroke of the wings, and as no means are here provided for restoring the wing to its primitive position the time of support is limited. The illustration suffices, however, to show that the work required in order to maintain a stationary position in the air by means of wings is equal to the work required to raise the total weight involved at the same rate as that at which it would fall were no work to be expended.

Of the total weight supported, namely, the animal and the parachute, the animal only is a source of power. Thus, while in "dynamically similar" combinations the total weight varies as the cube of the linear dimensions, the supporting area varies as the square, and the living power available varies, not as the total weight, but as the total weight less the weight of the supporting wing. It will be readily seen that if the animal can only deliver a certain amount of power per unit weight of body these conditions lead to an absolute limit to the weight of an animal which can sustain itself stationary in the air. For, suppose the total weight is $w=w_a+w_s$ (the weights, namely, of the animal and the parachute of area s), w_s must vary as $s^{\frac{3}{2}}$, and if the downward velocity is to be constant s must be proportional to w. From this it can be shown that the greatest weight an animal (incapable of climbing faster than some given speed) can have is $2b^3/3c^2$, where $b=w'/s'$ and $c=w_s'/s'^{\frac{3}{2}}$, w_s' and s' being known values of wing weight and wing area fulfilling the condition of falling with the required velocity when the total weight is w'. If we take $w_s'=w'/n$, the expression $2b^3/3c^2$ becomes $\frac{2}{3}w'n^2$.

As an example, suppose that 30 feet per minute is the limiting velocity at which an animal can continue to climb, and that the area of the parachute which will drop at the appropriate speed when the total weight of parachute and load is 1 lb. is 100 square feet, and also that the weight of the parachute alone is $\frac{1}{4}$ lb., then it appears that no animal could maintain itself stationary in the air by means of a parachute the weight of which exceeded $\frac{2}{3}(4)^2$ (or about $10\frac{1}{2}$ lb.), and the area required for this weight would be more than 1600 square feet. Thus, if no more favourable way of supporting a weight was available than the down stroke of a wing in still air, flight would be impossible for all except the very smallest animals.

As is well known, however, the vertical reaction on a slightly inclined plane moving rapidly in a horizontal direction enormously exceeds that which it would experience in dropping through still air, and although the proportionalities between the weights and the supporting area still remain, viz. $s \propto w$ and $w_s \propto s^{\frac{3}{2}}$, the actual weight which can be supported by a given area increases indefinitely as the horizontal speed increases.

If there were no such thing as air friction, the work expended in supporting a given load might also be reduced indefinitely, for the resistance to the horizontal motion (which, when the inclination of the plane is small, may be regarded as the horizontal component of the normal force) could be diminished indefinitely by decreasing the inclination.

Air friction, however, fixes a limit beyond which the inclination of the plane to the direction of motion cannot be advantageously reduced. Experiments have shown that this inclination is about 5°, and that then the ratio of the supporting force to the resistance lies between 5 and 7 (depending partly on the shape of the plane). A knowledge of the best angle of inclination and the ratio of the resistance to the force on the plane at right angles to its path afford means of determining the possible efficiency (see "Experiments on

Model Screws," R. E. Froude, F.R.S., Proc. Naval Architects, 1908).

Among birds, those which fly continuously seldom have the ratio of weight to wing area more than 1 lb. per square foot, and in many cases, such as hawks and swallows, the ratio is something like $\frac{1}{3}$ lb. per square foot; but whatever the ratio may be, so long as the animal can only give out a limited amount of power proportional to its weight, a definite limit can be assigned to the size and weight of the body which can sustain itself in flight by muscular action.

If the weight of the wing increased directly as its area such a limit would not exist. The weight of a flock of birds, for example, is limited simply by the numbers in the flock, and we only have to suppose the individuals to be connected by a light framework to convert the flock into a flying machine the wing weight of which is proportional to the wing area. To a certain extent, the biplane flying machine carries out the same idea, but in most of the existing types the weight of the connecting framework must to a great extent neutralise the reduction of weight which should accompany the reduced linear dimensions.

From what has been said it will be seen that so long as no engine was available which, with all adjuncts, such as fuel supply, framing, and wings, could raise the total weight much faster than could an animal of the weight of the engine only, there was no chance for the addition of flight to human accomplishments, and it is due to the advent of the internal-combustion engine that it is now possible to carry air-borne loads of more than 1000 lb. To carry heavy loads with a moderate wing area requires large horizontal velocities, and in such machines as have succeeded the load per square foot generally exceeds 2 lb.

The high velocity requisite is advantageous when the machine is launched and is pursuing a straight course, but it adds to the difficulties of starting and stopping, and is a restriction on manœuvring power. that is, it increases the radius of the circle in which the machine can turn. When a flying machine of weight w travels in a circle of radius r with velocity v the centrifugal force, F, is wv^2/rg, and if the plane of the circle is horizontal the upward component of the normal force on the wings is w, and hence the normal force is $(w^2+F^2)^{\frac{1}{2}}$ (nearly), and the inclination (β) of the wings to the horizontal in the direction of r is F/w.

The normal force on a straight course differs little from w. In flying in a horizontal curve, therefore, the normal force must be increased in the ratio $(w^2+F^2)^{\frac{1}{2}}/w$ if the velocity is to remain constant. To effect this the engine revolutions must be quickened and the fore and aft trim of the wings altered. In other words, it requires more power to fly in a curve than in a straight course at the same speed, although the increase is not important so long as F/w is small.

For example, if $v=50$ f.s. and $r=200$ feet, $F/w=0{\cdot}256$, the increase of power required is about 3 per cent., and $\beta=14^\circ$. For the same radius if $v=100$ f.s., $F/w=1{\cdot}56$. The power required is 1·86 times that for the straight course, and $\beta=56^\circ$ about.

I am not aware that any exact experiments have yet been made on the manœuvring capacity of flying machines, but the subject will have to be carefully investigated.

The three most important lines along which the development of flying machines should be pursued are those relating to intrinsic stability, ease of starting and stopping, and manœuvring capacity. It is improbable that any form is intrinsically stable at all speeds, but automatic devices may be introduced (as mentioned in my letters to NATURE of January 30 and December 24 1908) which will relieve the aëronaut of responsibility in this respect. Ease in starting and stopping implies the power of flying (at any rate, for a short time) at low velocities; while manœuvring capacity demands ready control of the angles at which the various supporting surfaces are presented to the air.

A. MALLOCK.

THE BRITISH ASSOCIATION AT WINNIPEG.

AS we go to press the seventy-ninth annual meeting of the British Association is being opened at Winnipeg, under the presidency of Sir J. J. Thomson, F.R.S., whose inaugural address is reprinted below. Following our usual custom, the addresses of presidents of most of the sections will be published in future issues of NATURE, and also accounts of the scientific proceedings of the sections.

This is the fourth time the association has met outside the British Isles, the previous occasions being Montreal (1884), Toronto (1897), and South Africa (1905). The last meeting of the association in Canada was very successful, the number of members and associates present being 1362. During the twelve years that have since elapsed, great progress has been made in all branches of science, and, though the people of Western Canada do not expect to contribute a very large part to the scientific proceedings of the sections, they anticipate interest in many of the subjects to be dealt with or discussed. Much interest in the meeting has been manifested in Canada and the United States, as well as on this side of the Atlantic. It is estimated that between 400 and 500 members have gone to Winnipeg from Europe, and it is hoped that the total number of members and associates attending the meeting will be at least 1500.

Generous financial support towards the expenses of the meeting has been given by the Dominion Government, the Government of Manitoba, and the city of Winnipeg, while the western provinces and cities have agreed to defray the expenses of an excursion to the Pacific Coast of a party of about two hundred office-bearers and distinguished guests of the association.

Excursions have been arranged for Saturday, August 28, to points of interest in the vicinity of Winnipeg, including Stony Mountain and the municipal stone quarries; Lake Winnipeg, St. Andrew's Rapids, and Selkirk; the wheat fields of Manitoba; the hydro-electric plant on the Winnipeg River. Members have also the opportunity of visiting various industrial works in the city of Winnipeg.

Evening receptions will be held by the Lieutenant-Governor at Government House, and by the local executive committee. Garden-parties have been arranged for several afternoons during the meeting including those to be given at the historic Lower Fort Garry by the Commissioner of the Hudson's Bay Company, at the Provincial Agricultural College, and by the Hon. Chief Justice Howell.

INAUGURAL ADDRESS BY PROF. SIR J. J. THOMSON, M.A., LL.D., D.Sc., F.R.S., PRESIDENT OF THE ASSOCIATION.

TWENTY-FIVE years ago a great change was made in the practice of the British Association. From the foundation of our Society until 1884 its meetings had always been held in the British Isles; in that year, however, the Association met in Montreal, and a step was taken which changed us from an Insular into an Imperial Association. For this change, which now I think meets with nothing but approval, Canada is mainly responsible. Men of science welcome it for the increased opportunities it gives them of studying under the most pleasant and favourable conditions different parts of our Empire, of making new friends; such meetings as these not only promote the